FACTORS INFLUENCING THE PRODUCTIVITY OF PEREGRINE FALCONS (*Falco peregrinus anatum*) IN THE FORTYMILE WILD AND SCENIC RIVER CORRIDOR, ALASKA

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ABSTRACT

I conducted the first comprehensive occupancy and productivity surveys of *Falco peregrinus* on the Fortymile River during 2000 and 2001. I tested feather samples of nine nestlings for mercury contamination, examined effects of human disturbance, and assessed correlations of nest productivity to aspect and distance from ponds.

Twenty and 22 nests were occupied in 2000 and 2001 and productivity averaged 0.88 and 1.33 nestlings per nest respectively. Mean feather mercury concentration was 3.85 ppm, and ranged from 1.88 ppm to 7.13 ppm. High variability in timing and intensity of disturbances and limited sample sizes precluded a study of disturbance effects. Peregrines selected nest-cliffs with southern aspects in 2001. North aspect nests were most vulnerable to failure in 2000. Nests within 6 km of a pond had higher productivity than those farther from ponds. The Bureau of Land Management is encouraged to continue annual occupancy and productivity surveys of the population.

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INTRODUCTION

Despite their successful presence on every continent but Antarctica, peregrine falcons (*Falco peregrinus)* have proven susceptible to human impacts. Contamination from the pesticide 1,1,1-trichloro-2, 2-bis-(p-chlorophenyl) ethane (DDT) led to the "endangered" listing of the American peregrine falcon in 1970 (Ratcliff 1967, Cade et al. 1971, Ambrose et al. 1988, Johnstone et al. 1996). Other cited threats and causes of population declines include: 1) the contamination of peregrine prey with other persistent organic pollutants and mercury, 2) disturbance from human activities, 3) habitat loss, and 4) direct persecution (Ratcliff 1988). The subsequent de-listing of the species in 2000 represents the success of great restorative and conservation efforts across the continent (Cade et al. 1988). Through their decline and recovery, peregrines have demonstrated themselves as bell-weathers of ecosystem health (Wilcox 1986). For this reason, and due to the continued existence of the factors that led to previous declines, it is important to continue the close monitoring and conservation of the species.

In 2000, the Bureau of Land Management (BLM) decided that comprehensive surveys of nesting peregrine falcons should be conducted in the Fortymile River watershed in eastern interior Alaska. While the BLM was aware that a significant population might nest within the watershed, their numbers had never been determined. A survey documenting the size of the nesting population and describing its reproductive success would provide necessary, and previously unavailable, information for the BLM's long-standing obligation of protecting peregrines in the multi-use management of the Fortymile Wild and Scenic River corridor.

In 2000 and 2001, I conducted the first comprehensive surveys of peregrine falcons nesting along the Fortymile River, documenting nest locations and reproductive success. To further understand this essentially unstudied population, I also collected data relevant to the management and conservation of peregrines enabling me to: 1) assess nestling mercury contamination levels, 2) investigate the feasibility of conducting human disturbance studies, and 3) analyze the influence of nest aspect and proximity to ponds in order to assess the differential distribution and success of nests along the river corridor.

This thesis is intended to aid the BLM's management and conservation of peregrines within the Fortymile Wild and Scenic River corridor by providing data on the Fortymile peregrine population, literature reviews of peregrine falcon natural history and factors affecting the population's viability, as well as management recommendations based on observations from the Fortymile and from the literature. In addition, by providing data to the U.S. Fish and Wildlife Service (USFWS), this thesis contributes to state and national peregrine monitoring efforts.

Natural History

Falcons are a cosmopolitan family of raptors, with at least one of the 19 total species inhabiting each continent of the world, except Antarctica (Palmer 1976). peregrine falcons (*F. peregrinus)* in the Americas occupy a range stretching from the Arctic coast of North America to wintering grounds at the southern tip of Argentina (Palmer 1976, Johnsgard 1990). Three subspecies of peregrines are found in Alaska: *Falco peregrinus pealei* inhabits the Aleutian Islands and southern coastal regions of the state, and is essentially non-migratory. *F. p. tundrius* migrates from wintering grounds in South America to breeding grounds north of the Brooks Range and west to the Seward Peninsula (south of the Brooks Range). *F. p. anatum* migrates from wintering grounds in South America to breeding grounds in the Alaskan interior (Ambrose et al. 1988). The subspecies *anatum* is the subject of this thesis, and all referrals to "peregrines" hereafter will refer to the *anatum* subspecies.

Peregrines prey primarily on waterfowl and shorebirds, as well as passerines (Palmer 1976, Johnsgard 1990). Small mammals can also be a lesser portion of the diet. In a study of peregrine prey selection during the nestling stage on the Yukon River in Alaska, prey remains included >55 avian species and groups of species (Hunter et al. 1988). The most frequently taken species were lesser yellow-legs (*Tringa flavipes*), gray jays (*Perisoreus canadensis*), and spotted sandpipers (*Actitis macularia*). Species that composed the largest proportion of the diet, based on biomass, were scaup (*Aythya affinis* and *A. marila*), green-winged teal (*Anas crecca*), lesser yellow-legs, and mew gulls (*Larus canus*). Fur of mammalian prey (red squirrel [*Tamiasciurus hudsonicus*], snowshoe hare [*Lepus americanus*], and/or voles [*Microtus spp.*]) occurred in only 5% of the castings.

Although peregrines are typically monogamous, some evidence of multiple partners has been found (Palmer 1976, Johnsgard 1990). Peregrines typically return to the same nest cliffs annually, but sometimes use alternate nesting sites (Palmer 1976, Johnsgard 1990). When establishing a nesting territory, peregrines typically return to their natal areas, frequently within the same river drainage (Palmer 1976, Ambrose and

Riddle 1988). Male peregrines arrive on the breeding grounds in early to late April and establish a territory. Nesting territories typically contain a cliff or steep bluff on which to locate a nest. Females arrive by late April to mid-May and, after courtship and re-acquaintance behaviors, select a location for establishing a “scrape” (Johnsgard 1990). A scrape consists of a small cleared area approximately 30 cm in diameter where eggs are laid, incubation, brooding and fledging takes place. Scrapes can be located on bare dirt or rock ledges, or in abandoned common raven (*Corvus corax*) or golden eagle (*Aquila chrysaetos*) nests (Palmer 1976).

Clutches contain up to four eggs. Eggs are laid at 2 d intervals over a 7 d period in mid-late May (Cade 1960, Palmer 1976). The female is the primary incubator and brooder; the male is the primary provider of prey to the female and nestlings. The 33 d incubation period begins with the laying of the third egg, resulting in slightly asynchronous hatching in mid-late June. Fledging occurs in late August to early September, and juveniles migrate south in late September, after the adults have left (Cade 1960, Palmer 1976). Parental feeding of juveniles may continue until migration.

Population Status

In 1970, after nearly 30 yr of steady population declines, the peregrine falcon was placed on the Endangered Species list. The population decline in peregrines and other birds of prey was caused by the organochlorine pesticide DDT and its break-down product 1,1-dichloro-2, 2-bis(p-chlorophenyl) ethylene (DDE) (Ratcliff 1967, Cade 1971, Ambrose et al. 1988, Johnstone et al. 1996). DDT and DDE are both lipophylic, environmentally persistent compounds, which bioaccumulate and biomagnify within the food chain (Hoffman et al. 1995, NAS 1978). Bioaccumulation refers to the long-term residence time of an external compound within an organism. Lipophylic compounds accumulate in the fatty tissues. Biomagnification refers to the additive bioaccumulation of an external compound in upper trophic level organisms, resulting in concentrations higher than in the surrounding environment. DDT and DDE interfere with a female's calcium deposition during eggshell formation, resulting in thin eggshells. These shells were often so thin they would break, precluding successful hatching (Ratcliff 1967).

While peregrines are still potentially exposed to DDT in portions of their winter ranges in Central and South America, the banning of the use and manufacture of DDT in the United States, combined with monumental captive breeding and reintroduction programs, has resulted in population rebounds (Johnstone et al. 1996). On August 25, 1999, the United States' peregrine falcon population was deemed recovered by the U.S. Department of Interior (USDOI) and removed from the Endangered Species list. The success of this recovery is being evaluated during a five-year mandatory monitoring period, during which the size and reproductive success of selected peregrine falcon populations across the nation will be tracked.

It is important to note the lesson learned from the population decline resulting from DDT; it serves as an example of the serious effect that lipophylic, environmentally-persistent compounds can have on avian populations. The population decline resulting from DDT contamination also demonstrates the value of raptors as indicators of environmental health and the potential of using raptor population health (such as productivity and recruitment) to measure our success in protecting the natural environment in our own interest and that of wildlife (Wilcox 1986).

Study Area

The study area lies within the Fortymile River Wild and Scenic River corridor, located in interior Alaska, approximately 300 km east of Fairbanks (Fig. 1). The Fortymile River consists of multiple, substantial, forking river tributaries, eventually forming a "main stem", which flows northeast to its confluence with the Yukon River in the Yukon Territory, Canada. The Fortymile is the largest congressionally-designated Wild and Scenic River in Alaska, with a total of 574 km of protected streams and rivers managed by the BLM. The river "corridor" refers to the area that is managed directly by the BLM. This corridor extends up to 3.5 km from the banks of the Fortymile River, and encompasses the entire area surveyed for nesting peregrines in this thesis.

The region has a sub-polar, continental climate with winter temperatures as low as –59°C and summers as warm as 32°C. Most of the 40 cm of mean annual rainfall is received as summer thunderstorms (USDOI 1973).

The watershed is characterized by rolling hills and steep unglaciated river and stream valleys, as well as areas of ponds and flooded oxbows. Steeper valley walls range from sheer rock faces over a hundred meters in height to treeless, sloping, grassy bluffs. Topographical relief varies from flat muskeg plains, 400 m above sea level to treeless mountaintops 1,800 m in elevation.

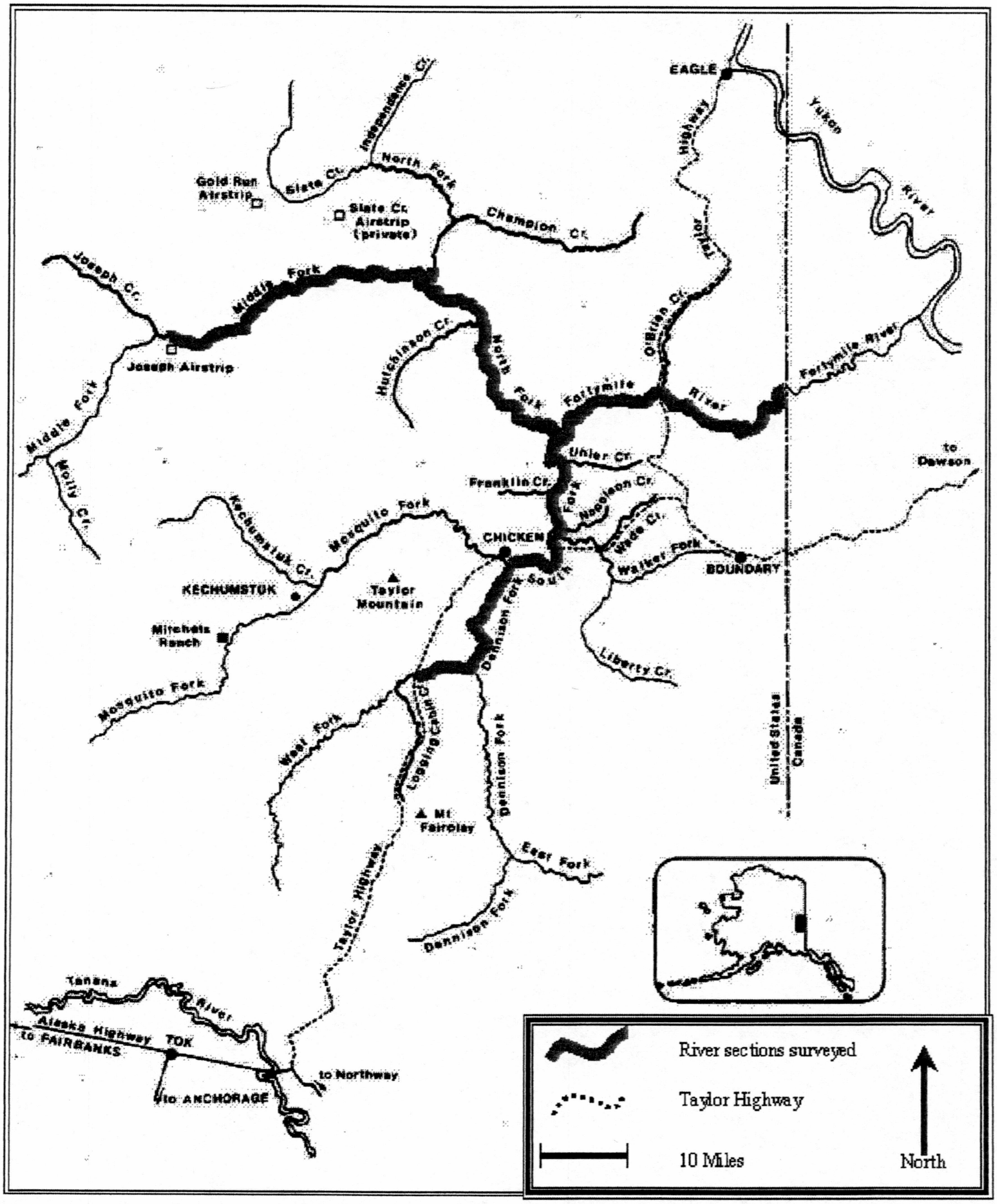

Figure 1. Map of Fortymile River study area in eastern interior Alaska.

Vegetative cover within the area includes narrow strips of white spruce (*Picea glauca*) stands along rivers and in well-drained stream valleys, black spruce (*Picea mariana*) taiga, as well as hillside stands of paper birch (*Betula papyrifera*) and aspen (*Populus tremuloides*). More comprehensive descriptions of the area can be found in the "proposed Fortymile National Wild and Scenic River, Final Environmental Assessment" (USDOI 1973).

The Fortymile River has a large variety of migratory shorebirds and waterfowl as well as migratory and resident songbirds that commonly occur in the diet of interior Alaskan peregrine falcons, as described by Hunter et al. (1988). These species include lesser yellow-legs, spotted sandpipers, bohemian waxwings (*Bombycilia garrulous*), green-winged teal, and mallards (*Anas platyrhynchos*).

The entire Fortymile watershed has been the location of varying intensities of gold mining since the end of the 19^{th} century. Early mining included hydraulic mining, bucket dredges, and drift mining. Hydraulic mining consists of huge water cannons (monitors) used to wash away non-gold-bearing soils, exposing gold-bearing gravel that is then washed through a riffle box. Riffle boxes utilize the higher relative density of gold to separate it from gravels and soil. Bucket dredges are large steam or electric powered dredges that float in streams and rivers. These dredges use a conveyor of "buckets" approximately a cubic meter in size to dredge the river bottom and sediments. These dredged sediments and rocks are then passed through riffle boxes before being re-deposited in the river behind the dredge. Drift mining involves digging mine shafts into gravel benches above the current location of the river. Gold-bearing gravels are then manually removed from the shaft and washed through a riffle box. Mercury adheres to gold, but not to other minerals and rocks of similar density to gold. For this reason, miners used mercury until the beginning of the 19th century to separate the gold from the other minerals caught in the riffle box. Current methods involve refined mechanical means rather than mercury in the final gold separation processes.

Currently, mining is restricted to suction dredging of approximately 140 km of navigable river-bottom and a few grandfathered upland “cat” mines. “Cat” mines involve bulldozers and other heavy equipment to work upland river benches. Suction dredge mining involves the use of gas powered “vacuums” mounted on floats in the river. A 4 to 12 inch (10.1 cm to 30.4 cm) diameter hose is operated by a miner/diver to suck up the river-bottom. River-bottom material is washed over a riffle box on the floating dredge, separating out the gold, before washing out the back of the dredge and returning to the river. Miners operating these dredges stage and camp in Long-Term Camps (LTCs), designated and managed by the BLM. Camps typically consist of two to four miners, associated tents and gear, and are located along the riverbanks near the claims. Most LTCs and dredging claims are accessed only by jet-boat.

After the discovery of gold in the Klondike, Yukon Territory, Canada, in 1896, the human population of the Fortymile watershed dropped from thousands to hundreds in a matter of days. In the mid 1970’s, during the peak of gold prices, the total annual human population within the entire watershed was estimated at 150. Now the only remaining permanent community within the watershed is the town of Chicken, Alaska, with a resident population of 25. During the mid 1970’s the summer population was estimated to be as large as 800, consisting mainly of gold miners (USDOI 1973). The current summer population within the watershed is well under 100.

The majority of the watershed is located within Yukon Military Operations Area (MOA) #3, training area for military fixed-wing aircraft. While low altitude overflights of military aircraft have been common in the past on stretches of the upper North and Middle Forks of the Fortymile, overflights of aircraft at altitudes less than 3000 m above next level were not observed during the course of this study. Considerable work has been done by ABR in monitoring the reactions of peregrines to the military overflights in the upper reaches of the Fortymile and surrounding Yukon River watersheds (Ritchie et al. 1997). The watershed is also considered to be one of the premier clear-water canoeing and rafting rivers in interior Alaska, due in part to its easy access to recreationalists via the Taylor Highway.

Surveys

Surveys of the Fortymile River peregrines have been sporadic and incomplete. While employed by the BLM in 1993-1998, I recorded incidental observations of peregrines during regular work trips on the river. These observations represented basic presence/absence, did not follow any preset protocol, and did not include nesting territory occupancy or productivity (BLM unpublished data). ABR conducted opportunistic productivity surveys of peregrine falcons in 1994 through 1997 but was not comprehensive in its coverage of the Fortymile drainage (Ritchie et al. 1998). Based on my earlier observations and ABR surveys, I estimated that approximately 12 breeding pairs were located in the study area. Since both sets of information were lacking in geographical extent and methodological rigor, and none of this existing information was sufficient for the management of the Fortymile peregrine population, new, more extensive and standardized surveys were required to support hypothesis testing.

In this thesis, I document population size, reproductive output, and nest locations of the Fortymile River peregrine population during the 2000 and 2001 breeding season. I compare the 1) nest productivity in the two years surveyed and 2) productivity of nests that were reoccupied with those that were not. In addition, I use observations of nesting chronology to judge the appropriateness of survey timing. Surveys provide the basis for all subsequent objectives of this thesis and will allow for the future tracking of population changes and impacts of management decisions by the BLM.

Mercury Contamination in the Fortymile River

A technical report published by the USFWS (Ambrose et al. 2000) concluded that while the concentrations of DDT and other organochlorides have decreased in Alaskan peregrine falcons between 1979 and 1995, concentrations of mercury in Alaskan interior peregrines have risen. Eggs laid between 1991-1995 were more likely to contain mercury concentrations in excess of safe thresholds than eggs laid between 1988-1990 (Ambrose et al. 2000). Reproductive effects of mercury contamination include direct effects, such as reduced clutch size (Heinz 1979, Barr 1986) and decreased egg hatchability (Borg et al. 1969, Fimreite 1971). Mercury contamination also impacts reproductive success through myelin degeneration in adults and nestlings, resulting in difficulties walking and flying, as well as in basic muscle movement and coordination (Fimreite and Karstad 1971, Heinz 1979).

Mercury, like DDT, is a lipophylic, environmentally persistent compound, which can bioaccumulate and biomagnify (Hoffman et al. 1995, NAS 1978). Mercury can enter a peregrine food chain through aquatic invertebrates living in contaminated sediments and water. Ducks and shorebirds, which comprise a large proportion of a peregrine's diet, consume these invertebrates. At each trophic level the concentration of mercury biomagnifies through its bioaccumulation in the animal's fat, resulting in potentially toxic mercury concentrations.

Currently, the geographic source or sources of the mercury contaminating Alaskan peregrines is not definitively known. Globally-deposited atmospheric sources of mercury include fossil fuel combustion, industrial manufacturing of chlorine-based materials, and metallurgical processes; these are predicted to continue to rise (Das et al. 1982, Hoffman et al. 1995). As a direct result of these industrial activities, mercury levels in the sediments of some rivers have increased four-fold since pre-historical times, and two-fold to five-fold in sediment cores from lakes and estuaries (Das et al. 1982). It is likely that peregrines are exposed to additional mercury contamination while on their wintering grounds in Latin America where, unlike currently in North America, mercury is still commonly used in gold mining, resulting in high levels of contamination in associated ecosystems (Malm 1998).

Existing data for mercury contamination in peregrine falcons for Alaska is based primarily on eggs. Because mercury contamination levels in eggs reflect the contamination loads of the falcon that laid the egg (Fimreite 1979), and because the falcon could have accumulated the mercury over a long period of time, including during migration, it is not possible to determine the geographical source of the contamination using eggs. One can begin to approach the question of geographic sources of mercury contamination through the sampling of peregrine falcons which have not yet migrated, and which live in an area where high mercury contamination is suspected.

The Fortymile River is a likely source of mercury contamination for peregrines that nest along it. Water quality analyses by Prussian et al. (1999) suggest that the Fortymile River water is highly contaminated with mercury (Table 1). While there can be natural sources of mercury in areas of high mineral content (Hellawell 1988) or resulting from changes which occur in flooded terrestrial habitats (Tremblay et al. 1993 in DesGranges et al. 1998), I hypothesize that the source of the Fortymile mercury is anthropogenic.

Remnant mercury left over from its use in the historic "gold rush" exists in the Fortymile watershed, where it was used to separate placer gold from fine sediments. Suction dredge miners still regularly encounter such deposits of elemental mercury in river sediments (Prussian et al. 1999).

Mercury concentrations in water from the Fortymile River have been recorded as high as 0.475 ppb (Prussian et al. 1999). This concentration is almost two orders of magnitude above typical background total mercury concentrations of 0.001 to 0.02 ppb reported for freshwater (Kudo et al. 1982, Bloom 1989, Mierle 1990). Mercury concentrations of 0.475 ppb are nearly an order of magnitude higher than the

Table 1. EPA's water quality criteria (ppb) for freshwater fish and aquatic life (from Hellawell 1988), average and individual heavy metal concentrations (ppb) of Fortymile River water samples collected at 10, 20, 40, 80, 160 and 320 m downstream from an operating dredge. Taken directly from Prussian et al. (1999).

			Distances samples collected downstream from operating dredge					
Metal	EPA	Mean	10m	20m	40m	80m	160m	320m
Copper	0.1	10.9	3.6	3.2	17.6	4.5	18.2	18.4
Lead	0.01	0.12	0.10	0.10	0.14	0.10	0.14	0.14
Mercury	0.05	0.2	0.212	0.200	0.200	NA	0.200	0.200
Zinc	0.01	2.34	2.10	1.64	2.67	1.93	2.80	2.90

“NA” Data not available.

Environmental Protection Agency's (EPA) recommended water quality criteria of 0.05 ppb for the health of freshwater fish and aquatic life (Hellawell 1988). The Fortymile River's mercury concentrations are more comparable to those of the Wabigoon River in northeastern Ontario, which received an estimated 10 metric tons of mercury from a chlor-alkali operation (Jackson et al. 1982, Parks 1989, Hoffman et al. 1995) and now has mercury concentrations up to 0.375 ppb.

In undisturbed aquatic ecosystems, mercury deposits can become less bio-available over time by being covered with non-contaminated sediments (Waldron et al. 2000, Wiener and Shields 2000). In contrast, the Fortymile River bottom is frequently disturbed and re-sorted by suction dredge mining operations. This disturbance may also explain the high concentrations of other heavy metals in the Fortymile River water (Prussian et al. 1999), such as copper, lead, and zinc (Table 1). At 320 m downstream from an operating dredge, heavy metal concentrations showed no signs of a decrease and remained orders of magnitude above the EPA's recommended levels.

Evidence of the bioaccumulation of mercury in the Fortymile food web is found in aquatic macro-invertebrates, which contain mean mercury concentrations 500 times the concentration of the surrounding water (Prussian et al. 1999). Inorganic (elemental) mercury, which has been methylated (converted to organic mercury) by bacterial action in an aquatic system, is more toxic and readily absorbed by organisms (NAS 1978). In addition, the bioavailability of the inorganic mercury in the Fortymile watershed could be accelerated by the low pH of the tannin-rich Fortymile River water, resulting in complexes formed between Hg and OH^- ions which increase chemical reactivity (Tsai et al 1975). Such complexes increase the incorporation of mercury in the tissues of fish (Tsai et al. 1975).

Based on the potential for high levels of mercury in the Fortymile River, and its ability to decrease the reproductive output of the peregrines nesting in the watershed, it is important to quantify the presence and evaluate the impacts of mercury present in the population. Therefore, for this thesis, I: 1) collect peregrine nestling feather samples to assess mercury contamination accumulated from prey on the natal grounds and 2) compare these mercury contamination levels of Fortymile peregrines with published levels of known physiological effects.

Human Disturbance

Disturbance of nesting peregrines by human activities has been a management concern throughout the species' range for decades. Numerous studies have been conducted on the effects of human disturbance due to pipeline construction, outdoor recreational activity, and military over-flights (Windsor 1977, Nelson 1979, Ritchie 1988 and 1998, Steidl and Anthony 1996). While individual raptor responses to disturbance can be highly variable, studies have found that human disturbance of nesting raptors by such activities as boating, mining, and construction can lead to decreases in reproductive success through nest abandonment, decreased predator vigilance, and lower hatching success due to reductions in time spent incubating and foraging (White and Thurow 1985, Fernandez and Azkona 1993, Anthony et al. 1995, Steidl and Anthony 1996).

Use of public lands, such as the Fortymile River, is growing across Alaska, raising the potential for disturbance of peregrines and other wildlife. Increased visitation of the Fortymile area is indicated by the doubling of traffic since 1994 on the Taylor Highway, an unpaved road, which runs through the watershed. This trend is expected to continue with the progressive paving of the route (J. Kowalczyk, BLM, personal communication). This increased ease of access to the river corridor via the Taylor Highway could lead to increased recreational boating and mining use, the main activities in the area.

Gold mining is the most significant and widespread activity managed by the BLM on the Fortymile River with fluctuating gold prices as the major factor driving gold mining activity. Due to the use of motorized suction dredges, motorboats, and LTCs by miners within the river corridor, it is also the most likely source of peregrine disturbance.

For proper management, it is important to understand the relationship between disturbance and the reproductive success of the peregrine population. To examine this relationship in the Fortymile, in this thesis I: 1) evaluate the feasibility of conducting a study of the effects of human disturbance on the productivity of the Fortymile peregrines based on survey results and observations of present disturbances, and 2) use results from the literature to make recommendations for mitigating potential disturbance from mining activities.

Nest Site Factors Affecting Peregrine Productivity

In examining factors potentially influencing the productivity of peregrine falcons and their nesting territories within a given watershed, it is important to consider natural, as well as anthropogenic, influences. Factors such as the height and aspect of nesting cliffs, weather, and abundance of prey influence reproductive success (Machmer and Ydenberg 1989, Bradley et al. 1997). My incidental observations of peregrines during 1993-1998 suggested a clumped distribution of nests. During the nesting period there were some stretches of river where I observed no peregrines at all, despite the presence of numerous seemingly suitable nesting cliffs.

Another factor that may influence peregrine nesting locations is prey distribution. Captive peregrines require 120-150g meat/day (Ratcliffe 1980). Juvenile wild peregrines wintering in England killed an average of two prey with a total weight over 400g daily (Baker 1967). During migration in Alberta and British Columbia, peregrines had hunting success rates of 9 to 20%, with 1-3 successful hunts per day with prey weighing 120 to 700g each (Dekker 1987). At this success rate, the estimated number of hunting attempts per day would range from 5-33. More prey is often killed than consumed, due to kleptoparasitism by other predatory bird species (Dekker 1987). During nesting, when one adult is providing food for a brooding adult and up to four nestlings, one would expect the number of hunting attempts to increase. However, I did not see large numbers of hunting sorties on the river.

During 1993-1998, I made frequent float-trips on the Fortymile River during the peregrine nesting and brooding periods. Each day, up to 12 hr were spent on the river, with trips lasting 1-8 d. During this extensive time on the river, I witnessed only four hunting sorties by peregrines. The prey species most commonly taken by Alaska interior peregrines, such as sandpipers, mallards, teal, gray jays and waxwings (Hunter et al. 1988), were present along the river. However, the most common waterfowl encountered on the Fortymile is the common merganser (*Mergus merganser*), an unimportant species in the diet of peregrines (Bird and Aubry 1982, Dekker 1987, Hunter et al. 1988). Based on the high number of peregrine hunting sorties (at least 5-33 per pair) expected, the low number witnessed, and the low availability of the most important prey species on the river, I hypothesized that the majority of peregrines' hunting takes place at locations away from the immediate river corridor. The distribution of these off-river hunting resources may influence the location of peregrine nests.

Potential off-river hunting sites may include numerous ponds along the river corridor where shorebirds and waterfowl congregate during nesting. Peregrines along the Yukon River forage up to 14 km from their eyries, with the majority of their foraging occurring within 3 km (McIntyre and Britten in Hunter et al. 1988), as reported by others (Beebe 1974, Bird and Aubry 1982, Enderson and Kirvin 1983). If peregrines conduct most of their foraging flights within 3 km of their nests, and ponds may be locations of high prey abundance, peregrine nests may be located preferentially near ponds.

Weather conditions can also affect reproductive output, and therefore should be considered as covariates in raptor disturbance studies (Shueck and Marzluff 1995). Weather can influence the frequency and success of adult raptor hunting sorties (Machmer and Ydenberg 1990, Shueck and Marzluff 1995). In addition, there may be direct negative impacts on the productivity of a nest through mortality of young due to precipitation (Bradley et al. 1997). Weather can work in concert with nest site characteristics, influencing both reproductive output and selection of nest locations. In Utah, north and east-facing cliff sites were preferred by nesting peregrines to avoid thermal stress to the young (Porter and White 1973). Peregrines are "far more sensitive" to heat, cold, and direct sunlight than prairie falcons (*Falco mexicanus*) or gyrfalcons (*Falco rusticolus*) (Palmer 1976). The comparatively high latitude of the Fortymile peregrine nesting population may result in a preference for southern aspects, in contrast to sites selected by birds nesting in Utah. However, this relationship may be confounded by the potential for hot sunny weather associated with eastern Alaska's continental climate.

Understanding the natural influences on nest site selection and productivity is necessary before interpreting the impact of anthropogenic inputs on nest site selection and peregrine productivity. To better understand the influence of nest site characteristics on nest site selection and productivity, I test the working hypotheses that nesting peregrines select: 1) south facing cliffs and 2) cliffs near ponds. I also test the working hypotheses that nests 1) on south facing cliffs have higher productivity than nests of other aspects and 2) with nearby ponds have higher productivity than nests without nearby ponds. In addition, I collected prey remains from aeries for comparison to presence/absence observations of prey species on rivers and ponds.

METHODS

Definitions

Terminology describing nesting activity follows the format of the USFWS raptor observation cards (Appendix A). The raptor cards define a nesting territory as "an area that contains, or historically contained, one or more nests… within the home range of mated birds, and where no more than one pair has bred at any one time." In practical terms, "nesting territory" is used to describe a cliff or series of nearly contiguous cliffs associated with historic or current nesting of one and only one pair. It was not possible to determine the exact extent of nesting territories because individuals were neither marked nor followed in this study. Aerie is used to refer to the actual nesting site or ledge on the cliff within the nesting territory. Falcon refers to the female of the species and tercel refers to the male. Territories are deemed occupied if a pair of peregrines was present, if a falcon was observed incubating, or if an individual displayed strong affinity for the territory and exhibited territorial defense activities (Postupalsky 1974). If these occupancy criteria were not met after four hours of observation, the nesting territory is defined as unoccupied. Chicks that were less than 34 d old (80% of mean age at first flight) are termed nestlings, and older chicks are termed fledglings (Steenhof 1987). Nesting success refers to the number of nesting pairs that successfully produce one or more fledglings. I defined productivity as the number of nestlings produced per occupied territory, which reach fledgling age (Steenhof 1987). Only occupied territories were used in calculating productivity because there was no practical method for enumerating the non-breeding, non-territorial segment of the population. Fledging age in peregrine falcons precedes actual fledging and is defined as 34 d of age. Between 34 d of age and time of actual fledging, mortality is considered minimal (Steenhof 1987). Productivity surveys should occur as close to this age as is logistically possible. In addition, this standardized chick age criteria should be considered in interpreting the results from productivity surveys. While the sum total of all observed nesting territories and fledglings is recorded, only those nests visited during both the occupancy and productivity surveys are used for calculating nesting success, productivity, and other reproductive parameters. Excluding nests found only in later surveys prevents over-estimation of these parameters.

Surveys

Field research was conducted during the spring and summer of 2000 and 2001. Prior to commencement of field research, permits were obtained from the University of Alaska Fairbanks Institutional Animal Care and Use Committee (IACUC), USFWS, and the State of Alaska Department of Fish and Game.

All data were collected within a 272 km portion of the Fortymile River system (Fig. 1). This portion of the river includes the Middle Fork (MF) starting from Joseph Airstrip, the North Fork (NF) from 1.6 km above its confluence with the Middle Fork, the West Fork (WF) from the Taylor Highway bridge at the West Fork campground, the Dennison Fork (DF) from its confluence with the West Fork, the entire South Fork (SF), lower Walker Fork (WKF), and the Main Stem (FM) of the Fortymile to the Canadian Border. Locations within forks of the Fortymile River are recorded in accordance with

BLM records measuring distances in river miles from last major confluence upriver (detailed maps available in USDOI 1983). The river sections surveyed encompass all sections of the river frequented by recreational boaters and/or gold miners. Access to additional portions of the Fortymile watershed would have necessitated the extensive use of helicopters, which was beyond the budgetary realm of this project.

Two surveys were conducted during each of the summers of 2000 and 2001. The first survey, conducted in early spring each year, documented occupancy of nesting territories. The second surveys were conducted mid-summer to document nest productivity. During the 2001 productivity surveys nestling feather samples were collected for mercury contamination analysis. Occupancy surveys were conducted from 19 May to 16 June, 2000 and 19 May to 8 June, 2001. Occupancy surveys coincided with the peak and end of the egg laying and incubation period for peregrines in interior Alaska (Cade 1960, Sherrod 1983, Steenhof 1987, C. McIntyre NPS, personal communication, T. Swem and H. Timm, USFWS, personal communication), which begins the end of the first week of May and continues to the first week of June. Productivity surveys were conducted 6 to 25 July in 2000 and from 1 to 20 July in 2001. Timing of the 2000 surveys was based on Cade (1960) and conversations with local researchers (R. Ambrose and H. Timm US Fish and Wildlife Service). Timing of surveys during the 2001 season was the result of rudimentary nesting chronology observations made during the 2000 season.

All surveys were conducted by a team consisting of myself and an experienced volunteer, following the procedures outlined in the USFWS Raptor Management Manual

(Postupalsky 1974, Pendelton et al. 1987). Travel within the study area was by non-motorized canoe or raft. All cliffs and non-forested slopes within the study area were observed for potential peregrine occupancy. Special attention was paid to areas with historic sightings of peregrines (BLM unpublished data). Observations were conducted using a 20 X 60 variable power Leica televid spotting scope and Cannon 12 X 30 image-stabilizing binoculars. Nest sites and ledges were not entered or approached during occupancy surveys. At each occupied nesting territory, a USFWS raptor observation card (Appendix A) was completed. Aerie locations were sketched and photographed to facilitate later relocation of nests during productivity surveys.

Productivity surveys involved re-visiting all occupied sites and categorizing each according to the number of adult peregrines present, breeding status, and the developmental stage of young.

Inter-annual productivity comparisons were conducted using two-sample t-tests, after testing for equal variances.

Mercury Contamination Sampling

Peregrine nestling feather samples were used to quantify their accumulation of mercury on the nesting grounds in the Fortymile watershed. Feathers reflect heavy metal concentrations in the blood stream during individual feather formation (Westermark et al. 1975, Scanlon et al. 1980). Unlike the contamination levels of eggs, which are representative of maternal contamination load, contamination levels within nestling feather samples are not derived from the mother in significant amounts (Westermark et al. 1975, Burger and Gochfeld 1997, Hughes et al. 1997). Nestlings have not yet migrated; therefore, the heavy metals incorporated into their feathers are representative of their natal ecosystem (Parrish et al. 1983, Scheuhammer 1991). The mercury concentrations in feathers of nestlings can be attributed to exposure from food items consumed by the nestlings during the growth of the sampled feather.

When appropriate, I collected nestling feather and addled egg samples during the 2001 peregrine productivity surveys. Sampling was deemed appropriate only if all nestlings in the nest were between two and four weeks old (Bloom 1987). Disturbance to the nestlings was minimized by not entering nests before chicks were two weeks old. After four weeks of age there is an increased likelihood of a nest visit resulting in premature fledging. Feather growth was not sufficient for sampling until three weeks of age. Nestling age was assessed previous to a nest visit using a spotting scope and a photographic aging guide (Cade et al. 1996). In addition, the nest also had to be safely accessible without risk of injuring nestlings with rock-fall.

To further reduce disturbance to nestlings and adults, total time spent within sight of the nest was minimized (15 to 90 min) and only one person entered the nest. The USFWS research permit further stipulated that only one nestling per aerie could be sampled to reduce handling and time spent in the nest. One nestling sample could represent the entire clutch based on the assumption of the clutch having consumed similar food, and therefore exhibiting comparable levels of contamination (Lindberg 1984). This assumption has been validated in mercury contamination studies of osprey (*Pandion haliaetus*) and eagle owls (*Bubo bubo*) (Odsjo and Olsson 1975, Hakkinen and Hasanen

1980). Given that peregrine flight feathers grow approximately 2-3 mm/d (Cade et al. 1996) a feather sample 1.5-2.0 cm long would represent the contamination accumulated over a week or more. For significant differences in contamination levels of siblings to occur, diets would have to differ consistently over this time period. The likelihood of this difference in diet did not justify the disturbance caused by sampling additional siblings.

Mercury levels may vary between different feathers on the same individual and even at different locations within the same feather (Berg et al. 1966, Lindberg and Mearns 1982). For example, down and flight feathers can contain different contamination levels, and if diet changed during the course of the formation of a feather the representative parts of that feather may contain different contamination levels (Berg et al. 1966, Lindberg and Mearns 1982). For consistency and data comparison purposes within and between populations, feather sample collection followed the methodology used by the Fairbanks Fish and Wildlife Office, U.S. Fish and Wildlife Service in 2000 (A. Matz, USFWS, personal communication), which is similar to that used by Parrish et al. (1983). The distal 1.5 cm from the fourth secondary remige was clipped with stainless steel scissors. This is the minimum amount required for analysis. The middle secondary remiges emerge before other contour feathers and are often the only feathers available for sampling at the time when entering the nest will cause the least disturbance. In addition, clipping of a secondary will cause the least potential interference with flight, relative to other flight feathers, and secondaries are among the first molted by peregrines (Parrish et al. 1983). Feathers were placed in individual, clean, dry Whirlpacks for storage until analyzed. All samples were provided to the Fairbanks Fish and Wildlife Office, U.S.

Fish and Wildlife Service. Mercury content analysis was performed at the USFWS lab in Patuxent, MD.

Collection of addled eggs followed protocols used by the Fairbanks Fish and Wildlife Office, U.S. Fish and Wildlife Service (Angela Matz, USFWS, personal communication). Addled eggs were placed in Whirlpacks and stored inside a padded container within a cooler for transport in the field. Eggs were refrigerated within 4 days. Fairbanks Fish and Wildlife Office, U.S. Fish and Wildlife Service, provided mercury and organic pollutants content analyses at the USFWS lab in Patuxent, MD.

Human Disturbance

During surveys, all human activity observed within the Fortymile River corridor was recorded. These data included date, location, number of people present, and the nature of the activities. I also used observations by BLM personnel and BLM LTC permitting records to determine the extent of human activities on the river during periods between surveys.

I used Fisher's exact tests to compare the productivity of nests located on different forks of the Fortymile River (which represented different numbers or densities of LTCs) and the presence of an LTC within 6 km, by year. I used t-tests to compare the productivity of nests that were located along jet-boat commuter routes to nests that were not along such routes, by year.

Nest Site Characteristics

Nest site characteristics documented included the aspect of the cliff on which an occupied peregrine nest was located and the proximity of occupied nests to ponds. Cliff aspect was determined in the field using U.S. Geological Survey (USGS) topographical maps and was recorded as half-quadrant relative to true north (i.e. South Southwest). USGS maps were used to locate all ponds within 14 km of the surveyed sections of the Fortymile. Universal Transverse Mercator (UTM) coordinates were obtained for the ponds and occupied nests using the website *topozone.com*. Distances from nest cliffs to all ponds within a 14 km radius were obtained by using UTM coordinates of nests and ponds and the Pythagorean theorem. Pond distances were grouped into kilometer increment distance categories, up to 14 km.

To test the hypothesis that the proportion of occupied nest cliffs didn't differ from the proportion of unoccupied nest cliffs by aspect, nest cliffs were grouped into three categories according to aspect (north, south, and east/west) by year. The distribution of occupied and unoccupied nest cliffs within these categories was compared using Chi-square. A Kruskal-Wallis test and a Wilcoxon-Mann-Whitney test were applied to the aspect categories above to test the hypothesis that peregrines nest productivity does not differ in relation to nest aspect.

To explore the hypothesis that nests with ponds nearby have higher productivity than nests without nearby ponds, nests were grouped into two categories separately by year: "high" nests had a productivity of 2-3 nestlings, and "low" nests had productivity of 0-1 nestlings. To estimate the distance at which ponds may influence peregrine production most, 14 individual, non-pooled, non-simultaneous Fisher's exact tests were run. The first test compared the proportion of nests in the productivity groups by the presence or absence of ponds within 0-1 km of the nest. The second test compared the proportion of nests in the productivity groups by the presence or absence of ponds within 0-2 km of the nest. Twelve more Fisher's exact analyses were run until the relationship between productivity and pond presence was tested for each 1 km increment between 1 and 14 km. The distance resulting in the most significant relationship between productivity and pond proximity was used to test the hypothesis that peregrines select nests with ponds nearby. In the analysis testing for the selection of nest sites based on pond proximity, nests were grouped into two categories according to the presence or absence of a pond within the distance determined as most significant above. The distribution of occupied and unoccupied nests within these categories was compared using Chi-Square.

In September of 2000, prey remains were collected from four accessible nests on the SF and FM of the Fortymile. All portions of animal parts were collected. Pellets were also collected. Remains were identified by comparisons with skins and skeletons in the University of Alaska Fairbanks teaching collection.

RESULTS

Surveys

A total of 20 nesting pairs of peregrine falcons was located on the Fortymile in 2000, and 22 in 2001 (Table 2). These totals were higher than the number of nests I had expected to find in the area (12 nests). During both field seasons, additional nests were located during the productivity surveys. In 2000, three nests could not be surveyed for occupancy due to river flooding. In 2001, three territories were initially misidentified as "unoccupied" and were later found to be "occupied." Only nests that were located during both occupancy and productivity surveys were used in calculating productivity and nesting success. Seventeen nests were located during both surveys in 2000 and 18 nests were located during both surveys in 2001. There was no significant difference in productivity between years ($t = -1.40$, $p = 0.1696$, $df = 33$).

Ten of the 17 (59%) 2000 territories were re-occupied in 2001. Nine of 18 (50%) territories were in new locations in 2001. I found no significant difference between the productivity of nests in 2000 that were reoccupied in 2001 (mean = 0.90 nestlings/nest) and those which were not (mean = 0.85 nestlings/nest) ($t = -0.09$, $DF = 15$, $P = 0.929$). Likewise, no significant difference was found between the productivity of new nests and reoccupied nests in 2001 ($t = -0.74$, $DF = 16$, $p = 0.4699$).

Two of the three north aspect nests were not re-occupied in 2001. The remaining north aspect nest was re-occupied in 2001, but failed in 2000 and 2001.

Nest density on the Fortymile River was approximately 1 nest every 12.4 river km (7.7 mi) surveyed in 2001 and slightly lower in 2000. In 2000, the mean distance from a peregrine nest to the next nearest nest was 8.4 river km (5.2 mi) and 5.8 straight km (3.6 mi). In 2001 the mean distance to the nearest nests was 6.8 river km (4.2 mi) and 4.5 straight-line km (2.8 mi). In 2000, the closest neighboring peregrine nests were 4.4 km

Table 2. Summary of nesting territory and reproductive parameters of peregrine falcons, Fortymile River, Alaska, 2000-2001.

Year	Occupied territories [total]*	Successful pairs [total]*	Failed pairs [total]*	Total fledglings [total]*	Productivity	Fledglings/ Successful pair
2000	17 [20]	10 [12]	7 [8]	15 [19]	0.88	1.50
2001	18 [22]	14 [17]	4 [4]	24 [27]	1.33	1.71

*Total refers to the sum total of all nesting territories located during the course of the field season, including territories which were only visited once during the field season. All calculations use the nests which were visited a minimum of twice during the field season.

(2.75 mi) apart with 5 river km (3.1 mi) between them. In 2001, the closest peregrine nests were 1.61 km (1 mi) apart, with 2.3 river km (1.4 mi) between them.

Nesting chronology

Hatching dates for 2001 were estimated by backdating from estimated ages of nestlings in successful nests. Incubation inception dates were estimated by subtracting 33 days from mean hatch dates (Burnham 1983). Mean date for incubation inception was 19 May. Mean date for hatching was 21 June ± 2 d (n = 9). The earliest estimated incubation inception date occurred on 18 May and the latest on 26 May. The earliest estimated hatching date was 16 June and the latest hatching date was 24 June. Mean incubation and hatching dates for the Fortymile River peregrines occur within three days of those recorded the same year for the peregrines nesting to the south of the Fortymile in Tetlin National Wildlife Refuge (Timm et al. 2002) and the Yukon River population to the north (Ambrose and Florian 2001).

Mercury Contamination

One feather sample was collected from each of nine different peregrine nestlings in nine different nests located on all of the major forks of the Fortymile River. Two samples each were collected from the SF, WF, and MF as well as the FM. One sample was collected from the NF.

Results from analyses of feathers conducted at the USFWS lab in Patuxent, MD, indicate that all feather samples contained detectable levels of mercury (Table 3).

Table 3. Dry weight mercury (Hg) contents of Fortymile River peregrine nestling feathers collected in 2001, the associated nest productivity, and sample detection limit.

Nest	Hg dry weight (ppm) mg/kg	Nest Productivity	Detection limit dry weight (ppm)
MF 22.8	1.88	2	0.0782
SF 24.6	2.28	1	0.0393
DF 13.1	2.47	1	0.0809
NF 32.2	2.58	3	0.09
MF 13.5	3.44	2	0.0799
FM 3.9	3.98	2	0.316
WKF 11.4	4.53	2	0.0585
DF 5.0	6.34	2	0.387
FM 7.2	7.13	1	0.144

Mercury concentrations in the feathers ranged from 1.88 to 7.13 ppm. Three of nine (33%) samples contained concentrations below background levels of 2.5 ppm. Two samples (22%) contained mercury concentrations above 5.0 ppm, the level at which "adverse effects" have been detected in a wide range of bird species during laboratory studies (NAS 1978, Eisler 1987, Burger and Gochfield 1997). The detection limit indicates the smallest concentration of the analyte that can be measured and reported with 98% confidence that the concentration is greater than zero.

Human Disturbance

During the period of territory establishment to fledging of the peregrines, seven LTCs were occupied along the Fortymile in 2000 and six in 2001 (Table 4). During this time period in 2000, only one suction dredge was observed in operation within the river corridor. Two dredges were observed operating in 2001.

In 2000, no LTCs, mining, or motorboat traffic occurred on the DF, the MF, or the NF of the Fortymile above "the Kink" (1 mile downriver of Hutchinson Creek, Fig. 1). During occupancy surveys (19 May - 16 June, 2000) no operating suction dredges were observed on any forks of the Fortymile and the only occupied LTCs or other mining camps were located on the FM of the Fortymile River at mile 16.1 and below the Fortymile Bridge at mile 21.0. During productivity surveys (6-20 July) eight LTCs were occupied on the Fortymile River: on the FM below the Fortymile Bridge at mile 17.8, 21.0 and 29.0, on the SF at mile 20.0, on the FM at miles 2.4 and 16.1 and on the NF at mile 40.0. No dredges were observed operating during the 2000 productivity surveys.

Table 4. Nest productivity of peregrine falcons, straight line km distance, and km distance measured along river course from LTCs, and number of LTCs with access routes which require commuting past the nest, on the Fortymile River, 2000 and 2001.

Year	Nest	Productivity	Straight/River km to LTC	Number of commuting routes passing nest
2000	NF 40.7	3	1.1 / 1.1	1
2000	SF 20.9	0	1.2 / 1.5	0
2000	FM 3.9	1	2.0 / 2.4	2
2000	SF 17.4	1	2.4 / 4.2	1
2000	FM 14.4	0	2.8 / 2.9	2
2000	SF 24.65	0	3.6 / 7.5	0
2000	NF 35.8	2	4.9 / 6.8	0
2000	SF 13.9	1	7.3 / 9.9	1
2000	FM 7.2	2	7.8 / 6.5	2
2000	WKF 11.3	1	11.3 / 17.7	1
2000	NF 29.0	0	11.3 / 17.8	0
2000	MF 37.7	0	17.8 / 30.9	0
2000	MF 34.3	1	19.4 / 36.5	0
2000	MF 26.05	0	21.1 / 49.9	0
2000	DF 13.1	1	24.3 / 40.3	0
2000	MF 22.8	0	33.2 / 55.1	0

Table 4 Cont'd

Year	Nest	Productivity	Straight/River km to LTC	Number of commuting routes passing nest
2000	MF 9.8	2	43.7 / 76.1	0
2001	WKF 11.4	2	0.3 / 0.3	1
2001	FM 14.4	1	2.8 / 2.9	1
2001	SF 13.9	0	4.1 / 7.6	0
2001	FM 7.2	1	4.1 / 5.7	0
2001	FM 3.9	2	8.1 / 11.0	0
2001	SF 20.0	1	11.3 / 17.5	0
2001	DF 13.1	1	14.2 / 23.2	0
2001	DF 5.0	2	19.8 / 36.2	0
2001	SF 24.65	1	21.2 / 14.2	0
2001	NF 40.7	3	24.3 / 43.1	0
2001	NF 32.1	3	33.2 / 57.0	0
2001	NF 25.4	2	40.5 / 67.2	0
2001	NF 24.0	0	41.3 / 65.0	0
2001	MF 35.1	3	60.0 / 119.4	0
2001	MF 32.0	1	61.6 / 124.4	0
2001	MF 26.7	0	64.8 / 133.0	0
2001	MF 22.8	2	68.0 / 139.3	0
2001	MF 13.5	2	71.3 / 154.4	0

Unexpected sources of potential human disturbance which had not occurred on the Fortymile River previously, but were present in 2000, included boat traffic and foot traffic on riverside bluffs associated with Morel mushroom (*Morchella spp.*) harvesters and an extensive drift-wood chainsaw firewood project directly beneath a peregrine nest at FM mile 14.4 (which failed).

In 2001 no LTCs, mining, or motorboat traffic occurred on the DF, the MF, or the NF of the Fortymile River above "the Kink." During occupancy surveys (19 May - 8 June), occupied LTCs or mining camps were only observed on the FM at mile 16.2 and below the Fortymile Bridge at mile 21.0. No dredge operation was observed during the 2001 occupancy surveys. During the 2001 productivity surveys (1 – 20 July), occupied mining camps and LTCs were observed on the FM at mile 10.7, 16.2, 17.8, 21.0 and mile 29.0, and on the SF at mile 9.4. During the 2001 productivity surveys, dredges were operating on the SF at mile 7.3, on the FM at mile 10.2.

LTCs varied greatly in size and duration. The largest mining camps were permanent residences with generators and multiple vehicles, and were often associated with upland "cat" mining. The simplest camps consisted of two people and two tents each. Most of these smaller camps were occupied only for a month or two, starting in mid-June. Therefore, few camps were occupied during the whole nesting season, some were occupied only during laying, and some were occupied only during the post-hatching and fledgling stage. The closest nest to an LTC was only 0.3 km away.

Jet-boats were used by miners to access LTCs from public boat launches located at SF 5.3 and FM 16.2. LTCs located on the South Fork are accessed from the SF boat landing. LTCs on the upper and lower FM, as well as the NF of the Fortymile River were accessed from the FM boat landing.

A statistical comparison of the productivity of nests, located on different forks of the Fortymile River representing different numbers or densities of LTCs, was not valid due to the overall low densities and high variability in timing and sizes of LTCs present during 2000 and 2001.

No significant relationship was found between nests with low productivity (0-1 fledglings) or high productivity (2-3 fledglings) and presence of an LTC within 6 km straight-line distance in 2000 (Fisher's Exact $p = 0.3971$, $df = 1$, $n = 17$) or in 2001 (Fisher's Exact $p = 0.2471$, $df = 1$, $n = 18$).

No significant difference was found between the productivity of nests that were located along jet-boat commuter routes, and nests that were not located along such routes in 2000 ($t = -1.57$, $p = 0.1380$, $n = 17$). An insufficient sample of such nests located on commuter routes ($n = 2$) was present in 2001, precluding statistical analysis.

Nest Site Characteristics

Nest aspect

In 2000, the proportion of occupied cliffs did not differ significantly from the proportion of unoccupied cliffs by aspect ($X^2 = 5.5470$, $p = 0.0624$, $df = 2$, Table 5). However, a trend of a higher proportion of south aspect nests used than expected was present. In 2001, a significantly higher proportion of nests were located on south-facing cliffs than expected ($X^2 = 17.6007$, $p < 0.0002$, $df = 2$).

Table 5. Approximate number of available nesting cliffs along the Fortymile River, number of cliffs occupied by peregrine falcons in 2000 and 2001, and expected distribution of cliff occupancy, all by aspect.

	Nest aspect		
	South	East/West	North
Available cliffs	28 (37%)	36 (47%)	12 (16%)
Observed Occupied cliffs			
2000	10 (59%)	4 (23%)	3 (18%)
2001	14 (78%)	4 (22%)	0 (0%)
Expected occupied			
2000	6.3	8.0	2.7
2001	6.6	8.5	2.8

Nests located on south-facing cliffs had a mean productivity of 1.1 ± 1.1 nestlings per nest (n = 10) in 2000, and 1.6 ± 0.9 nestlings per nest (n = 14) in 2001 (Fig. 2). All nests located on north-facing cliffs failed in 2000 (n = 3) and no north aspect nests were occupied in 2001. Each of the four nests with west- or east-facing aspects produced a mean of 1.0 nestling each year (SD = 0 and SD = 1.15, respectively) in 2000 and 2001. However, no significant difference was found between the productivity of nests with different aspects in 2000 (Kruskal-Wallis test value = 4.0877, $p = 0.1295$, df = 2, n = 17) or in 2001 (Wilcoxon-Mann-Whitney test value = 0.9935, $p = 0.3189$, df = 1, n = 18).

Pond proximity

Seven out of ten nests with ponds within 6 km produced 2-3 fledglings. Six out of eight nests without ponds within 6 km had only 0-1 nestling. A trend suggests that nests producing 2-3 fledglings in 2001 were more likely to have a pond within 6 km, than were nests producing 0-1 fledglings (Fisher's Exact Test $p = 0.0691$). The test lacked power due to a limited sample size (n = 18). Nest productivity levels had to be combined in groups to fulfill the requirements of the Fishers Exact two by two table. I tested this relationship further by comparing published peregrine productivity data from the Tanana River (Ritchie et al. 1998) with the presence of ponds near nests. A significant, positive relationship was found between nest productivity and ponds within 3 km when I applied the same analysis to Tanana River nests (Fisher's Exact $p = 0.0406$, n = 29).

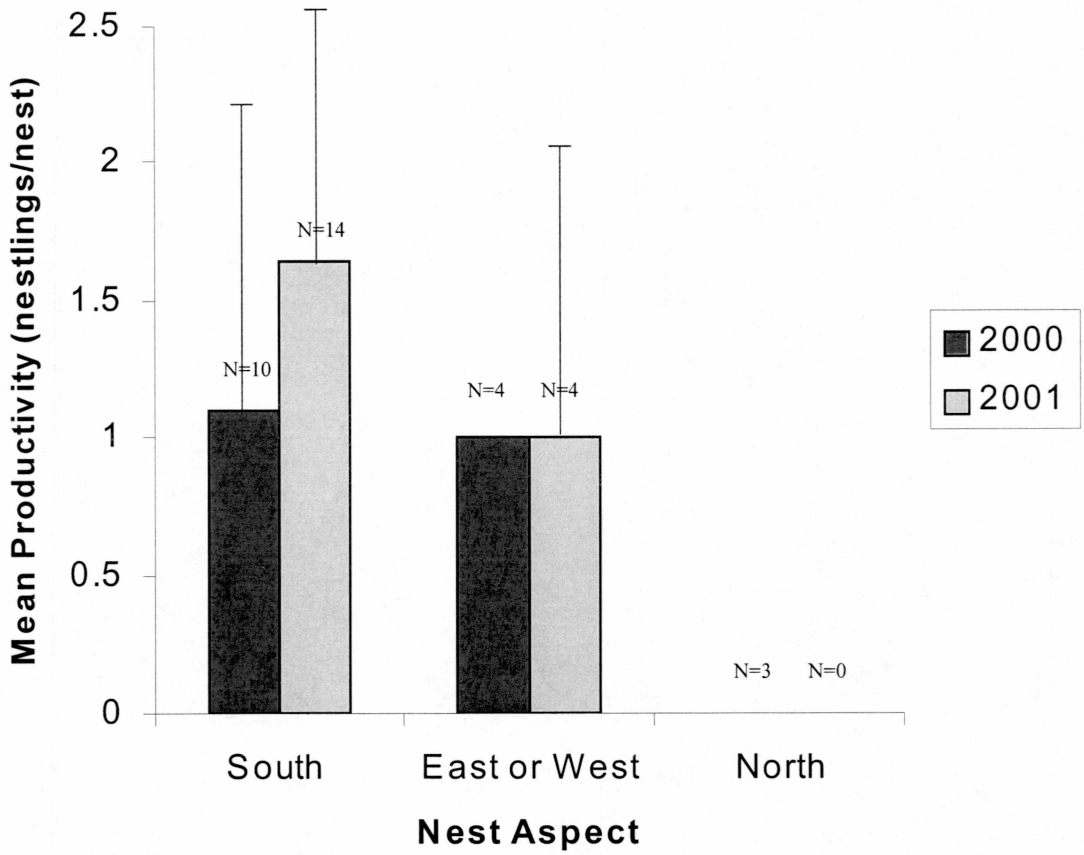

Figure 2. Mean productivity (fledglings per nest) of peregrine falcons on the Fortymile River in 2000 and 2001 by nest aspect.

The proportion of occupied nests with ponds within 6 km versus the proportion of unoccupied nests with ponds within 6 km did not differ from random in 2000 (X^2 = 0.1487, p = 0.0.6998, df = 1) or in 2001 (X^2 = 0.1482, p = 0.7003, df = 1).

DISCUSSION

In this section I will discuss the results of the Fortymile River peregrine population surveys, mercury contamination analyses conducted on nestling feathers, feasibility of examining the effect of human disturbance on peregrine productivity, and the influence of nest cliff aspect and proximity to ponds on nest site selection and productivity.

Surveys

The 20 and 22 nesting pairs of peregrines located during the 2000 and 2001 surveys respectively, were nearly double the population of 12 nesting pairs I predicted based on my earlier incidental observations of peregrines. Incidental surveys are likely to severely underestimate the population size of nesting peregrines, due to the secretive nature of some individual peregrines and the imprecise timing and presence of the observers within the river corridor during the narrow window of key observation periods for determining occupancy and productivity. Previously, BLM personnel recorded peregrines as present only when obviously perched or when displaying active defensive behavior such as vocalizations. A majority of successful nest locations during occupancy surveys conducted for this thesis occurred after an hour of cliff observation and involved seeing the incubating falcon only briefly during a period of her movement. The most frequent and obvious clue for locating nests was the sudden arrival of the tercel delivering food to the incubating falcon. Approximately half of the nests in 2000 were located in this manner. White-wash was never a useful indicator of peregrine occupation. Since fewer than half the nesting pairs were observed displaying vocal defensive behavior during incubation, it is not surprising that incidental observations missed a large number of nests likely occupied by incubating falcons. Vocal territorial defense behavior was much more commonly observed after hatching, than during occupancy surveys.

According to the nesting chronology observed during 2001, surveys were conducted at the correct time. Occupancy surveys began on 19 May, at the peak of the incubation inception. Occupancy surveys should be finished before the first hatch on 16 June.

The low productivity and nestling success observed in 2000 reflected an Alaskan interior-wide trend in low peregrine reproductive success. This likely resulted from a rainy summer that caused direct mortality of nestlings (R. Ambrose, USFWS, personal communication). During the first week post-hatching, Chicken, AK precipitation totaled 11.9 cm (21 June to 4 July) in 2000 but only 2.59 cm for the same time period in 2001 (Western Regional Climate Center unpublished data). Mean ambient temperature was 15.4° C 21 June to 4 July in both years. Ambient temperature ranges were 7.5° - 24.0° C in 2000 and 6.2° - 24.8° C in 2001 (Western Regional Climate Center unpublished data).

Nestlings are especially vulnerable to the effects of weather during their first 14 d (Palmer 1976). Rainy weather can also lower adult raptor hunting success (Machmer and

Ydenberg 1990, Shueck and Marzlueff 1995). The higher reproductive success of the Fortymile River peregrines in 2001 mirrored higher peregrine reproductive success throughout interior Alaska, presumably in response to a drier summer.

Selection pressures regarding nest cliff aspect may vary strongly with summer weather conditions, reducing the measurable effect. Selection pressure would be weaker during drier summers and stronger pressure for selecting south-facing cliffs would occur during summers with above average precipitation. While there were no significant differences in productivity between aspects in either year, one interpretation of the selection of south-facing nest cliffs in 2001 is that this could be a response to failures of all north-facing nests during the rainy 2000 nesting season.

Mercury Contamination

The results of the mercury contamination testing provide a challenge for interpretation due to the small sample size and wide range in concentrations: from below background to concentrations that may impair reproductive ability. However, the significance of the concentrations of mercury found in the nestling feathers has bearing on three lines of thought: The first addresses the question of the source of the mercury in the Fortymile watershed, whether it is natural or anthropogenic and the extent of the contamination within the peregrine food web. The second is the relative contamination levels of the Fortymile versus other populations. The third line of inquiry regarding mercury contamination in the Fortymile watershed examines the potential clinical effects on the peregrines of the mercury contamination levels found.

My hypotheses regarding mercury contamination of the Fortymile River were based on potential residual mercury remaining in the river system from gold mining in the late 1800's and early 1900's and from continued re-exposure due to river-bed disturbance from current suction dredge gold mining. The resulting synthesis of hypotheses about sources and routes of mercury contamination through the food chain in the Fortymile is restated in the following scenario:

1) If mercury does not occur in the watershed in naturally high concentrations, mercury would be most prevalent in the main river channel sections where the heaviest historic mining occurred,

2) Ducks and shorebirds consuming invertebrates living in contaminated sediments or preying on species occurring in contaminated sediments would ingest and bioaccumulate mercury,

3) Peregrine nestlings consuming ducks and/or shorebirds containing high mercury concentrations would accumulate high levels of mercury,

4) Since peregrines hunt most often less than 14 km from their nests, these mercury concentrations might reflect the mercury contamination of prey species feeding within that radius, and

5) Therefore, peregrines in areas of the Fortymile where historic mining was most prevalent would be expected to have the highest mercury concentrations.

Some, but not all, portions of this hypothetical line of thinking are supported by the data, with important implications for future study and management.

My assumptions of mercury distribution within the Fortymile appear generally correct, and are elucidated further by Crock et al. (2000). Water samples collected by the USGS from more than 24 feeder streams throughout the Fortymile watershed contained mercury concentrations of <0.005ppb (Crock et al. 2000). Such widespread, low concentrations suggest that no significant natural mercury source occurs within the watershed. Four samples were collected on the major portions of the river and also contained mercury concentrations <0.005ppb. Two samples were collected from the FM, 11 and 48 km downstream of where Prussian et al. (1999) collected their highly contaminated water samples. The samples of Crock et al. (2000) and Prussian et al. (1999) are otherwise in agreement regarding concentrations of four other heavy metals in the water of the Fortymile River and its tributaries. Differences in sampling methodology should only result in differences of precision, but not of accuracy. Therefore, both papers' sampling methods and results are considered equally valid. The only way to reconcile the dramatic differences in low mercury concentrations found by Crock et al. and the high mercury concentrations, as well as actual lumps of elemental mercury, found by Prussian et al. (1999) is to assume that mercury contaminated "hot spots" must exist within the areas of the Fortymile River where historic mining occurred. Such hot spots may be the result of significant spills of mercury or represent leaching from areas of high mercury use. Such mercury contamination may be trapped within sediments and only available as a result of the disturbance of those sediments, and within close range downstream of the disturbance. In order to map such hot spots, it might be most affective to conduct intense sampling of sediments within the main river channel, comparing both historically mined and un-mined stretches. By sampling sediments, rather than the water, one would not be relying on the unpredictable disturbance of the sediments by dredging or flooding to suspend the mercury into the water column.

Linking mercury contamination sources within the Fortymile through pathways in the peregrine's food web is not clear and unequivocal. With the current data, it is not possible to determine the source of the mercury contaminating the peregrine nestlings. Data from similar projects are not yet available for comparisons among populations. Such comparisons should consider differences in prey composition. Consumption of different combinations of trophic levels could also result in differential contamination levels (Lindberg 1984, Ambrose et al. 2000).

Future investigations of the Fortymile as a source for mercury contamination in the local peregrine population would also benefit from the contamination testing of the young of peregrine prey species. Essentially all of the peregrine prey species feed on non-migratory animals, or on plants, while in the Fortymile. Pre-migration juveniles of these prey species would contain mercury contamination attributable only to their natal area. Such analyses would provide a strong test of the hypothesized link between mercury contamination in the Fortymile peregrines, their prey, and the mercury deposits in the river.

Prey arriving already contaminated with mercury, rather than becoming contaminated entirely by sources in the Fortymile watershed, is more congruous with the results and observations related to the importance of ponds as prey sources, but does not explain the wide range of contamination levels across nests. Ponds along the Fortymile

River are not the result of mining and are not disturbed repeatedly, and therefore are not likely sources for mercury contamination. If ponds are where peregrine prey are observed most often, and where the majority of the peregrine hunting takes place, mercury contamination of the river would not explain the contamination of nestlings and prey. If a relationship existed between high mercury contamination of nestlings located far from ponds, and therefore perhaps being provided with more river-feeding prey, one might still suspect the river as a significant contamination source. However, the sample size of nine nests is too small for this statistical testing, and such a trend is not clearly evident. While the nest with the highest mercury concentration was less than 5 km away from the "hot spot" sampled by Prussian et al. (1999) and did not have a pond within 16 km, nests with second and third highest contamination levels had several ponds located within 2 km; one of these nests was located in an un-mined fork of the river. Cahill et al. (1998) found no relationship between mean mercury concentrations in osprey nestling feathers and the distance of their nest from a mercury mine.

However, if contamination of peregrine prey occurred prior to their arrival in the Fortymile, assuming a random distribution of prey species among peregrine hunting territories and that each nestling represents a sample averaging the contamination of multiple meals, one would expect less variation in the contamination levels of the nestlings. The distribution of contamination results might be, to some extent, an artifact of small sample size.

Peregrine populations have been found to contain mercury concentrations similar to, and higher than, those recorded on the Fortymile. Swedish peregrine feathers collected in the nineteenth century contained concentrations of 2.5 ppm (NAS 1978). Berg et al. (1966) found concentrations from juvenile peregrines in that era to have mercury concentrations of approximately 3.5 ppm. Mercury concentrations remained at these levels in Sweden until contamination levels rose >40 ppm in the 1940s, coincident with mercury use as a fungicidal seed dressing (Berg 1966). Concentrations of 2.5 ppm are considered background industrial age levels of mercury (NAS 1978, Scheuhammer 1991).

Three of nine feather samples collected on the Fortymile contained mercury concentrations less than 2.5 ppm. No clear explanation of these relatively low values is apparent. These three nest locations varied greatly in geographic location, historic and current mining use, and pond proximity. The sample size of nine nests lacks power for testing an effect of mercury concentration on peregrine reproduction within the Fortymile and no clear trend is evident.

Interpretations of the physiological impacts of contamination levels present in the Fortymile peregrines are hindered due to the absence of studies linking mercury concentrations in peregrine nestling feathers to physiological effects and the confounding factors involved in extrapolations from studies conducted on other age groups and species. Different species can tolerate different levels of mercury without displaying detrimental effects. The lowest level of contamination with discernable reproductive problems found by testing a broad range of species is 5 ppm (Eisler 1987). Eggs laid by individuals with this mercury concentration suffered reduced hatching success. Above this concentration nearly all species of birds are reported adverse effect on productivity or behavior (Table 6). There are exceptions. Mercury concentrations high enough to result in sterility in one species fail to elicit a measured response in other species (Table 6). Molting of feathers allows birds to lower their contamination loads (Furness et al. 1986), and different feathers from the same bird may vary significantly in their mercury contamination (Furness et al. 1986). Falcons can also reduce their own body load of mercury through egg laying. The presence of concentrated selenium in the diets of mercury-contaminated birds ameliorates some of mercury's harmful effects (Bowerman et al. 1994, Burger and Gochfeld 1997). Seabirds are able to de-methylate mercury, thereby reducing its toxicity (Das et al. 1982, Honda et al. 1990). Therefore, such confounding disparities in the responses of birds to differing concentrations of mercury found in the literature may not only reflect actual species' physiological differences, but methodological differences in relation to timing of molt, type and location of feathers sampled, sex, dietary selenium concentrations, and egg laying.

No abnormal behaviors were observed in the Fortymile peregrine population during the surveys. Future surveys of the Fortymile peregrines should include structured behavioral observations, designed in cooperation with professionals familiar with peregrine behavior. In experimental studies of captive birds fed contaminated prey, signs of mercury poisoning were often not apparent up to 52 d after ingestion. Observable, abnormal behaviors and physiological conditions in mercury contaminated avian species include: decreased activity levels, difficulty flying to perches, decreased food consumption, emaciation, difficulty in balancing, head tremors, and "incoordination" (Heinz 1979).

Table 6. Literature survey of mercury levels in sampled bird species' feathers and the associated physiological or reproductive effect (ppm on dry weight basis).

Species		Mercury level	Effect	Source
Black ducks	*Anas rubipes*	65.6	No duckling survival	Finley and Stendall 1978
		40.8	Lowered reproduction	Finley and Stendall 1978
Osprey	*Pandion haliaetus*	>40	No reduction in nestlings produced	DesGranges et al. 1998
Sparrow hawk	*Falco sparverius*	40	Sterility	Solonen and Lodenius 1984
Bald Eagle	*Haliaetus leucocephalus*	21	None	Bowerman et al. 1994
Mallard	*Anas platyrhynchos*	9-11	Reproductive and behavioral deficits	Eisler 1987
White-tailed Eagle	*Haliaetus albicilla*	5-11	Eggs seldom hatched above these levels	NAS 1978
various bird spp.		5-10	Reduced hatch of eggs	Eisler 1987
Raptors		1-5	Estimated background of raptors	Scheuhammer 1991, Berg et al. 1966, Lindberg and Mearns 1982, Parrish et al. 1983, Honda et al. 1986

Productivity surveys (1-20 July, 2001) were well centered on the dates during which nestlings would be safe if a nest was entered. However, nestlings had not grown long enough feathers for mercury contamination sampling until the middle of the second week of July. After July 28 all nestlings were older than 34 d. The target week for feather sampling would then be July 18 to July 25.

In summary, the important conclusions related to mercury contamination of the Fortymile River peregrines are:

- Mercury contamination of the Fortymile River is thought to be restricted to a few "hot spots" resulting from historic mining.
- Linking mercury contamination of peregrine nestlings to a source within the Fortymile would be aided by the sampling of juvenile and adult prey species.
- My sample size lacked power to test for a relationship between nestling mercury contamination and nest productivity.
- Determining the exact effects of the mercury present in the peregrine nestlings was hindered by the lack of comparable studies, and the large number of confounding factors across species, ages and methodologies.
- While not extremely high, the average mercury contamination levels found in the Fortymile peregrine nestlings are above background, and some may be high enough to cause neurological damage, which may be evident in abnormal behavior.

Human Disturbance

Mining activities were very inconsistent in duration and intensity, precluding replication. Individual peregrines can vary greatly in their response to disturbances, and there is great natural variability in productivity. Such individuality can be the result of factors such as experience, age, hunting success or stress. Herbert and Herbert (1965) concluded about peregrines: "…perhaps the most notable fact about them was that they varied greatly as individuals. No two individuals nor pairs were the same in behavior. No two pairs, it would seem had the same problems. Each aerie was a world of its own, distinct in pattern (p. 68)."

The inability to test for an effect of disturbance due to lack of statistical power does not preclude the presence of an effect. It also does not mean that disturbance studies could not be conducted in the future, utilizing a larger peregrine sample size or more homogenous mining disturbance sample. The types of human activities observed on the Fortymile are similar to disturbances to peregrines in other studies. Therefore, it is likely that some peregrines may be disturbed by these activities on the Fortymile. A majority of disturbances from human activities observed were related to activity around LTCs, jet boats, and semi-stationary motorized suction dredges. While local topography, differences in species, an individual raptor's behaviors, previous exposure of the raptor to disturbances, characteristics of the disturbance's approach or location, and weather conditions all are variables in the response of a raptor to disturbance, some common patterns emerge from the literature. It is possible that the sudden appearance or a jet boat around a corner below a peregrine nest may be similar to the disturbance caused by the sudden appearance of an aircraft. During incubation and breeding, eggs and chicks are often located on top of the feet of the falcon (Palmer 1976). If a sudden disturbance flushed a falcon from a nest, direct mortality of offspring could occur by the falcon knocking chicks or eggs out of the nest (Awbrey and Bowles 1990). Conversely, predictable, more gradual approaches of jet boats, or of stationary suction dredges within nesting territories, may be more similar to the human activities to which some raptors become habituated when nesting in cities or alongside highways (Herbert and Herbert 1965, Ritchie et al. 1998). Numerous studies have found significant negative impacts on raptor productivity attributable to general human activity similar to activities associated with LTCs (Broley 1952, Snow 1973, Nelson 1977, Nelson and Nelson 1978, Theberge and Gauthier 1978, Windsor 1979).

Public concern was generated by this project as to the effect of nest visits on the peregrines. No effect was detected. All fieldwork was successfully carried out in accordance with techniques described above; they have been found to not significantly disturb the nesting pairs or their offspring. The chronology of sampling does not allow for statistical testing for an effect of researcher disturbance. Since nest visits (mercury sampling) were conducted only during the second of the two field seasons, no productivity data was taken after nest visits took place. However, initial observations of nest occupancy by the BLM during the spring 2002 field season did not indicate an impact from the nest visits (K. Cooper, BLM, personal communication). At least six of the nine nests entered in 2001 were re-occupied in 2002; in comparison with three of the eight nests that were not entered in 2001 and were re-occupied (K. Cooper, BLM, personal communication).

Nest Site Characteristics

The hypothesis that there is a positive relationship between peregrine productivity and pond proximity to the nest was supported by the analyses of the Fortymile and the Tanana River data.

The importance of ponds to nesting peregrines is further illustrated by the fact that the distance from nest to pond at which a relationship was achieved changed with the two different densities of ponds associated with the Fortymile and Tanana populations. The density of ponds within the Tanana watershed is more similar to the density of ponds on the Yukon, where peregrines were found to forage within 3 km of their nests. The significant relationship between productivity and ponds within 3 km for the Tanana watershed supports the Yukon River observations made by McIntyre and Ambrose (In Hunter et al. 1988). In the Fortymile watershed, where pond density is much lower, it is logical that the distances from nests to ponds are greater. The value of this analysis is not in merely quantifying the relationship between productivity and ponds, but in establishing the radius about a nest in which ponds are used by peregrines for hunting. Knowing this radius, which may differ with pond densities, has obvious importance in tailoring land management and conservation to specific populations.

In summary, the important conclusions related to the role of pond proximity and aspect in relation to nest site selection and productivity of the Fortymile River peregrines are:

- South facing nest sites are selected more often than north facing sites.
- There is not evidence of selection for nest sites located within 6 km of a pond.
- Productivity of nests located within 6 km of a pond was higher than of nests without a pond within 6 km.

MANAGEMENT RECOMMENDATIONS

Surveys

Occupancy surveys

At a minimum, occupancy surveys should be conducted each spring between May 19 and June 16. Occupancy surveys provide the information upon which all following investigations and management actions are based. Since peregrine nest-site occupancy precedes most mining activity in the river corridor, the surveys allow the BLM to comply with the USFWS management recommendations (Appendix B) in regards to the placement of LTCs relative to active peregrine nests.

Productivity surveys

Productivity surveys are highly encouraged. Productivity surveys provide the opportunity to gather a long-term database with which to track the reproductive health of the population, increase knowledge of additional potential nesting sites, and to gauge the accuracy of occupancy surveys.

Occupancy and productivity surveys should be conducted deliberately and intensely in accordance with the methods outlined and cited in this thesis. Strict adherence to consistently conducting surveys during the proper dates is required for unbiased comparisons between years. Incidental observations have proven inadequate. Survey teams should consist of two people, at least one of which has peregrine survey experience. At no time during surveys should untrained personnel enter or approach aeries without an expressed purpose reviewed and permitted by the USFWS.

Both occupancy and productivity surveys should involve the recording of data on raptor nesting cards (Appendix A) at the time of observation. A copy of the completed survey cards should be provided by the BLM to the USFWS each year for their monitoring records. Survey data from raptor cards should continue to be compiled by the BLM in the Raptor Inventory spreadsheet provided to the K. Cooper of the BLM Fortymile Management Team, Tok, AK.

To facilitate the location of historically used aeries, electronic copies of photographs and/or sketches of 27 aeries occupied in 2000 and 2001, have been provided to K. Cooper, of the BLM Fortymile Management Team, Tok, AK. However, all cliffs and bluffs should be examined for occupancy, not just historically used sites. Nest locations should continue to be recorded with photographs, and sketches to facilitate future surveys. Such records are important in providing continuity despite high turnover of field personnel. Written descriptions of nest locations have proven inadequate.

Mercury Contamination

Mercury contamination sampling of the Fortymile's peregrines should continue only if it can be incorporated into a larger study organized in cooperation with the USFWS. Coordination with the USFWS allows for consistency in methodologies, important in the comparisons of long-term datasets. Coordination also allows for the pooling of data, providing a larger sample size, enabling wider-ranging questions to be asked and answers to be more definitive.

Mercury contamination studies should include testing for a relationship between mercury contamination levels of nestlings and the productivity of the nest. The study should also include the investigation of a peregrine-specific contamination level at which reproductive output is significantly depressed. Current literature is based on such a wide variety of methodologies, species and confounding factors that interpretation is not definitive. Basing indices of 'levels of reproductive effects' on nestling contamination and field observations would generate a large amount of data quickly, and with minimal disturbance to the peregrines, while maintaining a geographical relationship to the nesting grounds. The database and conclusions generated by such a study would provide necessary benchmarks and data for use in potential future legislative or management actions regarding mercury contaminations of peregrines in interior Alaska.

If future studies lead to the conclusion that the mercury contamination levels of the Fortymile peregrines are higher than of other populations, further investigations examining the link between potential mercury "hotspots" and the peregrine food chain are recommended. Investigators should consider including testing the contamination levels of peregrine prey species nestlings, as well as pond and river sediments. Testing prey species nestlings provides a better geographic link, than testing adult prey, to contamination resulting from feeding in the Fortymile. Sediment sampling for mercury contamination, rather than water sampling, may provide a more accurate map of mercury "hot spots" within the Fortymile. Sediment samples should be collected along all forks of the Fortymile to allow for the investigation of the hypothesis that the mercury contamination results from historical mining. Ponds sediments should also be tested, due to their importance as a prey source.

Human Disturbance

Management of human activities

The Fortymile Management Team's adherence to the USFWS recommendations for management of human activities near peregrine aeries, with the modifications listed below, should be standard.

- The recommended minimum protected zone of high-quality habitats, such as ponds and other wetlands, should be extended from the recommended 3.2 km (2 mi) radius around an active nest to 6 km (3.7 mi). Such protective measures should be considered not only by the managers of the LTC program, but also by those who manage upland mining operations which may endanger such habitats, such as at the confluence of the Mosquito Fork and WF.

Future disturbance studies

To gauge and track the levels of human activity present on the Fortymile, the Fortymile Management Team needs to develop a system to accurately monitor the use of the river corridor by visitors. Decreased travel time between Fairbanks and Chicken resulting from the paving of the Taylor Highway will likely lead to increased recreational boaters, prospectors and commercially guided river-trips. Such data would greatly facilitate any future disturbance studies.

Any future disturbance studies must take into account the small sample size of peregrines available on the Fortymile River. It is likely that disturbance studies would only be statistically feasible if they included additional peregrine sub-populations, such as the Charley River, the Yukon River and Tanana River sub-populations.

A program of interpretive signs at appropriate river access points and pamphlets educating visitors about conservation of natural resources, such as peregrine falcons, within the Fortymile River corridor are highly recommended. A large proportion of visitors use the Fortymile River, without contacting BLM personnel. Signs and pamphlets would help narrow this gap.

With consistent monitoring, adaptive, proactive management of its diverse, multiple uses, and education of the visitor, mining and recreational use of the Fortymile can continue in concert with a healthy peregrine population.

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APPENDIX A: Raptor Observation Cards.

RAPTOR NEST/EYRIE RECORD CARD (FEB 1989)

TREE NEST-SPECIES:

1. LIVE TREE 4. ARTIFICIAL
2. SNAG 5. CAVITY IN TREE
3. NEST BOX/PLATFORM 6. OTHER

TREE HEIGHT (M): E A

TREE DIAMETER (CM): E A

HEIGHT OF NEST IN TREE (M): E A

DOMINANT HABITAT TYPES (up to three within .5 km of nest)
1. CLIFF
2. UNVEGETATED GROUND
3. WET MEADOW
4. DWARF SHRUB MEADOW (tundra dominated by grasses or sedges)
5. GRASS MEADOW
6. DWARF SHRUB MAT (dwarf shrubs <0.4 M high)
7. LOW SHRUB THICKET (shrubs 0.5 - 1.1 M high)
8. MED. SHRUB THICKET (shrubs 1.2 - 2.4 M high)
9. TALL SHRUB THICKET (shrubs 2.5 - 5.0 M high)
10. DECIDUOUS FOREST
11. CONIFEROUS FOREST
12. MIXED DECIDUOUS-CONIFER FOREST
13. SCATTERED WOODLAND AND DWARF FOREST
14. ARTIFICIAL HABITAT 15. OTHER
16. MARINE (dist. km) E A
17. RIPARIAN (dist. km): E A
18. LACUSTRINE(LAKE) (dist. km): E A
19. RIVER / STREAM (dist. km): E A
20. OTHER PERRENIAL WATER (dist. km): E A

FOR CLIFF NESTS - ABOVE CLIFF:
(habitat types) BELOW CLIFF:

GROUND NEST - SITUATION:
1. LEDGE ON CLIFF 4. OPEN HILLSIDE
2. STICKNEST ON CLIFF 5. LEVEL GROUND
3. CAVITY (POTHOLE) ON CLIFF 6. OTHER

CLIFF ROCK TYPE: 1. SED 2. IGN 3. MET
SPEC. FORMATION:

CLIFF HEIGHT (M): E A

CLIFF LENGTH (KM): E A

HEIGHT OF NEST ON CLIFF (M): E A

ELEVATION OF NEST ABOVE SEA LEVEL (FT):

ASPECT OF SLOPE:

ASPECT OF NEST:

NEST CONDITION: 1. GOOD 2. POOR 3. REMNANT ONLY

NEST ACCESSIBILITY (to ground predators): 1. EASY 2. MOD. DIFFICULT 3. VERY DIFFICULT

DISTANCE TO HUMAN ACTIVITY (KM): E A

HUMAN ACTIVITY VISIBLE FROM NEST? 1. YES 2. NO

TYPE(S) OF HUMAN ACTIVITY:
1. TRAIL 7. CONSTRUCTION
2. ROAD 8. RESEARCH
3. BOATING 9. MINING
4. AIRCRAFT 10. OIL / GAS
5. BUILDING(S) 11. LOGGING
6. AGRICULTURE 12. OTHER:

CIRCLE ANY THAT APPLY:
1. PHOTO OF CLIFF TAKEN
2. PHOTO OF EYRIE TAKEN
3. EYRIE DESCRIP. ATTACHED
4. PREY REMAINS COLL.
5. EGG(S) COLLECTED
6. EGG SHELLS COLLECTED
7. WHITEWASH AT EYRIE
8. OTHER WHITEWASH ON CLIFF
9. OVERHANG AT EYRIE
10. AFTERNOON SHADING?: a. YES b. NO c. UNKNOWN

BANDING AND BAND RECOVERY INFORMATION

AGE	SEX	AVISE NO. - COLOR / LEG	BAND CODE - COLOR / LEG

RAPTOR OBSERVATION RECORD CARD (FEB 1989)

OBSERVER NAME AND ADDRESS:

MAP NAME:

STATE - MAP # - NEST TERR. # - SITE # - YEAR

SPECIFIC AREA (DESCRIBE):

OTHER NO. (e.g. Agency No.):

UTM-N or LATITUDE:

UTM-E or LONGITUDE:

SPECIES (COM NAME OR AOU ABBREV.):

DATE	TIME	SUR MET	NO. ADS	NO. SUB	NO. EGGS	NO. NEST	AGE NEST	NO. FLG	ACTIVITIES
					E A	E A	E A		
					E A	E A	E A		
					E A	E A	E A		
					E A	E A	E A		
SEASON SUMMARY	TOTAL:								

SURVEY METHOD:
1. FOOT
2. VEHICLE
3. BOAT
4. PLANE
5. HELICOPTER
6. INCIDENTAL OBS.

ACTIVITY / BEHAVIOR (May Be More Than One)
1. PERCHED
2. FLYING
3. HUNTING/FORAGING
4. FEEDING ADULT
5. TERR. DEFENSE
6. VOCALIZING
7. BODY CARE
8. COURTSHIP
9. NEST BUILDING
10. INCUBATING
11. BROODING
12. FEEDING YOUNG
13. COPULATING
14. OTHER:

OFFICIAL NEST STATUS

NOTES, MAP, OR PHOTO ATTACHED? 1. YES 2. NO

REMARKS (Moult In Adult Pair, Prey In Nest/Eyrie, Etc.):

APPENDIX B: Recommended Protection Measures For Peregrine Falcons During the Nesting Period.

The following protection measures are intended as general guidelines and may not be appropriate in all situations. The level of protection needed may vary with topography, vegetation and the sensitivity of individual birds to human activity. When feasible, proposed activities should be examined on a case-by-case basis by a biologist knowledgeable of the habits and behavior of peregrine falcons.

A. Within 1 mile of nest sites:

1. Require aircraft to maintain altitudes of 1,500 feet above next level from April 15 through August 31.

2. Prohibit all ground level activity from April 15 through August 31 except on existing thoroughfares.

3. Prohibit habitat alterations or the construction of permanent facilities.

B. Within 2 miles of nest sites:

1. Prohibit activities having high noise levels from April 15 through August 31.

2. Prohibit permanent facilities having high nose levels, sustained human activity, or altering limited high-quality habitat (e.g. ponds, lakes, wetlands, and riparian habitats).

C. Within 15 miles of nest sites:

1. Prohibit alteration of limited high-quality habitat that could detrimentally and significantly reduce prey availability. Of particular concern are ponds, lakes, wetlands, and riparian habitats.

2. Prohibit use of pesticides – The only exception may be limited to non-aerial application of approved non-persistent insecticides at supply bases.

From: "Recovery Plan for the Peregrine Falcon – Alaska Population." Region 7. USFWS in Cooperation with the Alaska Peregrine Falcon Recovery Team. 1982. 51 pp.

APPENDIX C: Additional Data

In addition to the peregrine data, observations were recorded for approximately 12 active raven nests, two active golden eagle nests, one great horned owl nest, and a red-tailed hawk nest. The presence of other wildlife such as mammals, waterfowl, transient raptor species, as well as numerous passerine species, was recorded when observed from the river. Waterfowl species observed on the river included: goldeneye (*Bucephala clangula*), green-wing teal, mallard, common merganser, harlequin (*Histrionicus histrionicus*), American wigeon (*Anas americana*), northern shoveler (*Anas clypeata*), bufflehead (*Bucephala albeola*), and white-winged scoter (*Melanitti deglandi*). Common mergansers constituted almost 50% of all waterfowl observations. Fifteen percent of waterfowl sightings were harlequin ducks, and 9% of sightings were mallards and wigeon. Spotted sandpipers were ubiquitous on the riverbanks, but were not quantified.

APPENDIX D: Identifiable prey remains from four peregrine falcon nests on the Fortymile River, 2000.

Nest	Prey remains
WKF 11.3	5 Kinglet (R*egulus spp.*) sized feet found in pellets
SF 13.9	Two mew gull wings, 1 kestrel (*Falco sparverius*) tail feather, 2 mallard skulls, 1 shorebird or passerine skull (beak missing), woodpecker (*Picoides spp.*) feathers, pellets containing only unidentifiable feathers.
FM 3.9	Nine robin (*Turdus migratorius)* or varied thrush (*Ixoreus naevius*) wings, 1 spotted sandpiper wing, 2 dead peregrine chicks ages five and eleven days, wigeon skeleton, Bohemian waxwing head, robin or varied thrush head, 3 kinglet-sized feet in pellets.
FM 7.2	One entire wigeon skeleton, 1 mallard skull, 2 different shorebird feet, 21 pellets containing only unidentifiable feathers.